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Comparative Results between Loudspeaker Measurements Using a Tetrahedral Enclosure and other Methods

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ABSTRACT

A major problem for the loudspeaker and transducer industries throughout the world, is an inability to rely upon measurements routinely exchanged between suppliers and customers.

This Paper updates (Consistently Stable Loudspeaker Measurements Using a Tetrahedral Enclosure - eBrief: 123) published in 2013 (1), with comparative measurements using results by other people, equipment and methods: Small IEC Baffle in Anechoic Chamber and Large IEC Baffle Outside vs a TTC 350.

These Test Chambers give us the capability to approach "Design Quality" measurements easily throughout the entire supply chain, reducing errors and improving quality whilst driving down the cost of measurement.

1. BACKGROUND

Throughout the world an enormous amount of time goes into measuring loudspeakers, only for the customer to do the same measurements again as they cannot trust the data received from the suppliers.

This is not due to our equipment as hardware, software and microphones have long ceased to be significant sources of errors. I believe that it is the lack of a consistent environment and measurement geometry that is the real reason for the inconsistencies that we currently see. To make things worse everyone has a different "Test Box" and most of them give a wildly varying performance, often at odd's with the original design intention.

There are standards for making loudspeaker measurements notably from the IEC and JIS. Unfortunately both of these standards are relatively old and do not really suit the ways modern loudspeaker drivers are produced or tested in today's world. Many of the issues are summarised by Alan S Phillips' paper: 'Measuring the True Acoustical Response of Loudspeakers' (2).

2. ANECHOIC CHAMBER MEASUREMENTS

Why is there so much variation in measurement results? Well one problem has come up time and time again—inconsistency due to set-up variations. This is odd because pretty well all of the calibration routines and procedures assume that it's the equipment that varies. This may have been the case in the past but today it is unlikely as modern equipment is far more stable and consistent than it has ever been.

In my experience the problem really comes down to the human factors. If sufficient care is taken and you use an appropriate anechoic chamber with a correctly set-up IEC baffle or JIS test box you can get reliable measurements that can be reproduced by another equally well-trained, disciplined and equipped individual elsewhere in the world. So we need to ask ourselves a different question: 'What is it about these standards that means in practice the results from them are so variable as in many cases to be useless?'

- Measurements using both methods need to be made in an anechoic environment
- Most anechoic chambers are designed to minimise external noise influences [1]
- It is essential that the baffle or test box together with microphone be correctly set up but there is little if any guidance on how to do this
- It is essential that the acoustic environment around the baffle or test box and microphone be completely clear of items that can reflect sound, but it's not unknown for chambers to be cluttered up as they are often used as large storage spaces
- The anechoic chamber must be designed so that nothing interferes with the measurements, though they often have floppy mesh floors that are unstable or protruding beams

From the above there are so many possibilities it is no wonder that we cannot achieve consistently reliable measurements at different locations.

3. MOUNTING A LOUDSPEAKER

In order to make consistent measurements the best way is to use a series of removable and interchangeable standardised measurement 'sub baffles', one for each type of loudspeaker drive unit to be measured: The exact design of these is changed to mate accurately to the loudspeaker driver being tested without causing any damage . These sub baffles are then mounted into the main measurement baffle. This could be an IEC baffle, a 2π baffle built into one wall of an anechoic chamber, a JIS test box or into a Test Chamber.

Focussing on a sub baffle its main requirements are:

- To provide a simple and reliable method of changing between drivers
- To provide a precisely repeatable and secure mounting for the driver
- To change the acoustical loading of the driver as little as possible
- To accommodate a large range of physical sizes of drive units

4. WHAT IS THE SIMPLEST POSSIBLE LOUDSPEAKER TEST ENVIRONMENT?

When I asked this question it then struck me that many of the most consistently reliable measurements that I had made in the past had often used a microphone in a corner pointing toward the loudspeaker.

So how could this be applied in practice? This paper concentrates on a tetrahedral enclosure, basically constructed of three identical right angle triangles and one equilateral triangle. We could in principle use a corner of a room with a single triangular baffle and sub-baffle. A major advantage of this structure is the lack of conventional standing waves.

The example shown fits neatly into a corner, whilst maximising the baffle area, the corners have been squared off and filled with acoustic absorption [2]. A microphone coming out from the corner at a 45° angle and facing the flat internal baffle at a fixed distance completes the overall structure.

How does this benefit us? Quite simply we now have both a defined acoustic environment, minimising modal problems and we have a defined mechanical geometry, removing many of the potential set-up problems that beset our current standards. Because the design is much smaller and simpler it is much less likely to be tampered with and should retain its mechanical and acoustical integrity for much longer with needing continual upkeep.

The next steps are (i) defining the mechanical aspects of the tetrahedral enclosure and the mating 'sub baffle(s)', (ii) deciding what size(s) the overall design should be.

Obviously a design suitable for a Micro-Speaker and a design for a 30 inch Sub-Woofer loudspeaker drive unit

[1] Not necessarily of the highest importance when measuring a loudspeaker at 70 to 100dB SPL

[2] This external shape is covered by EU Registered Design number 002292532

will have very different requirements. Currently there are four sizes (3):

Photo's of a Tetrahedral Chamber without and with a SEAS H1207 Driver (4) [3] is shown below: -

Figure 1. TTC 350

4.1. BEM and FEA Modelling

A Boundary Element Model was made with ABEC 3 (4) [4] and subsequently verified with Finite Element Modelling from Pafec (4) and measurements.

4.2. Calibration Methodology

We know from the simulations and measurements that though the pressure is nearly equal everywhere inside the enclosure (at Low Frequencies), it is not absolutely flat with respect to frequency. Richard Small used this technique in his paper 'Simplified Loudspeaker Measurements at Low Frequencies' (6) over 40 years ago to measure low frequencies without an anechoic environment. With modern equipment and software we can do better.

Don Keele showed part of what we need with with his paper 'Low-Frequency Loudspeaker Assessment by Near-Field Sound Pressure Measurement' (7), Keele shows that we can directly measure the far field low frequency output accurately in the near field, so if we know that our Transducer is "Pistonic" at *Low* frequencies and most are, then it does not matter whether we measure at the 'Front or the Back' of the Cone/Diaphragm as at low frequencies they will be the same.

We can derive a correction curve either theoretically (3) or (4) or we can derive a basic correction curve by measuring the external Near-Field response of a drive unit and subtracting this from the measured internal (pressure response) inside a tetrahedral test system and apply this as a microphone correction curve.

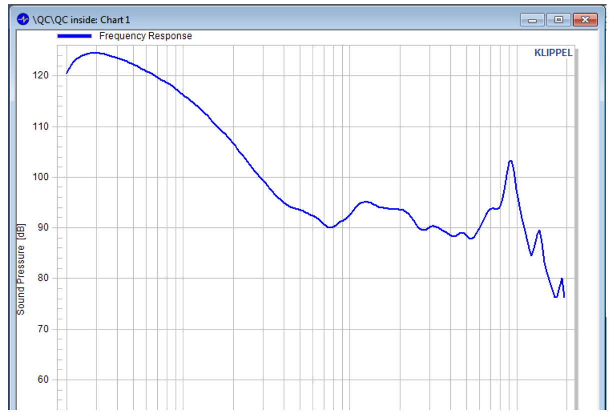

Figure 2. Internal Frequency Response

Looking at the curves there is a rising (pressure) response below 700Hz, and generally smooth responses looking like a 'Normal' Anechoic Response above 1 to 2kHz.

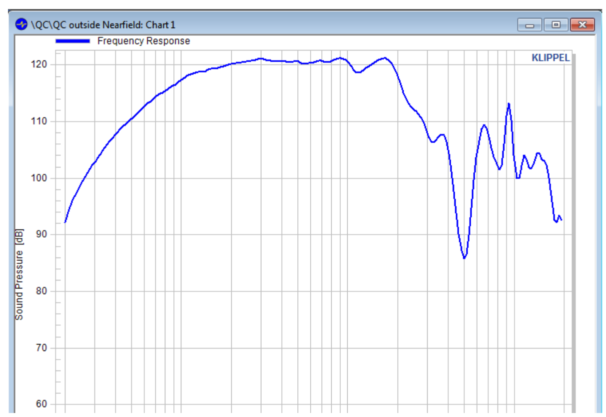

Figure 3. External Near Field Frequency Response

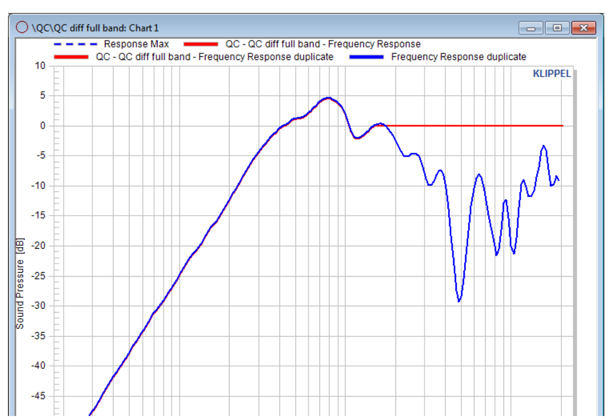

Figure 4. Correction (Difference) Curve Frequency Response

[3] kindly supplied by SEAS Fabrikker AS of Norway
[4] detailed in my previous paper (1)

We simply "Zero" all the data points above say 1400Hz [5]

4.3. Measurements

The measurements in this report were produced with the following equipment: [6]

- Klippel QC System with MI 18 HL Microphone.
- CLIO 11 from Audiomatica with MIC -03 Microphone.
- Tetrahedral Test Chamber - model TTC 350.
- Small IEC Test Baffle in Anechoic Chamber.
- Large IEC Test Baffle outside.

The measurements are shown are of a SEAS H1207 Driver in a variety of measurement conditions above...

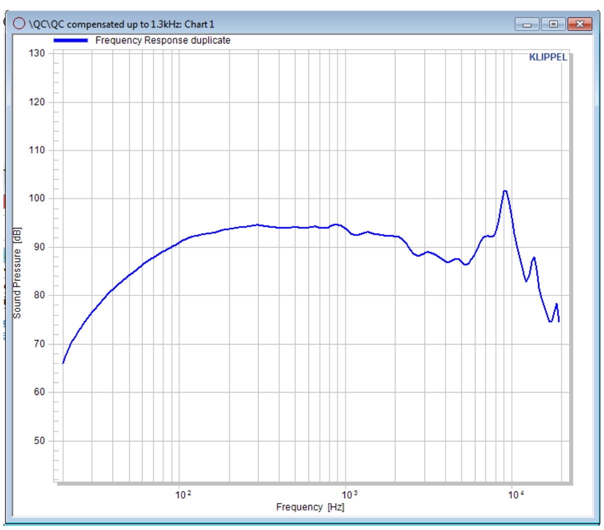

Figure 5. H1207 Driver Response in TTC 350

[5]Assuming the driver used *is* Pistonic to 1400Hz

[6]The measurements in this report were made SEAS, Stefan Irrgang and Dave Berriman.

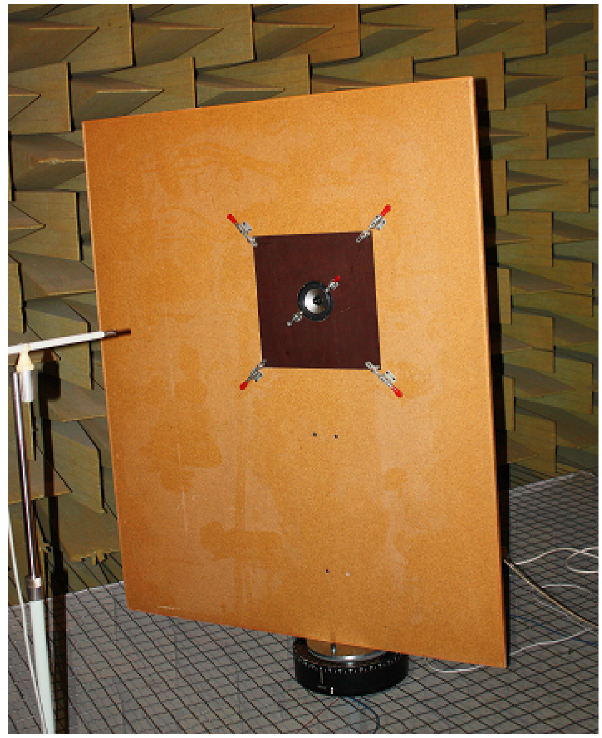

Figure 6. H1207 in a Small IEC Baffle

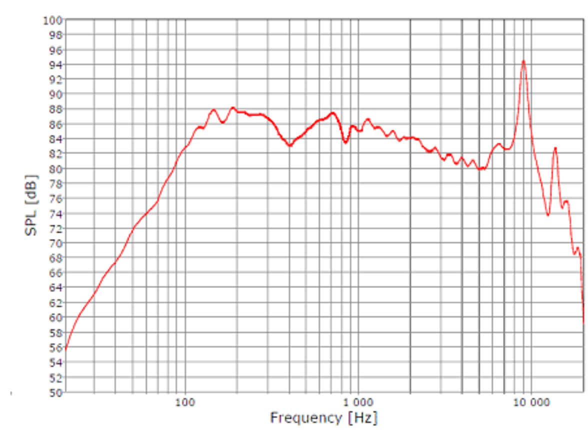

Figure 7. Response of a different H1207 in a Small IEC

Clearly even a Small IEC Baffle in an Anechoic Chamber is not ideal as can be seen clearly in the ripples and the roll up at low frequencies. We move now to the same driver in a Large IEC Baffle

Figure 8. TTC350 and Large IEC Baffle [7]

We have a measurement at 1m distance

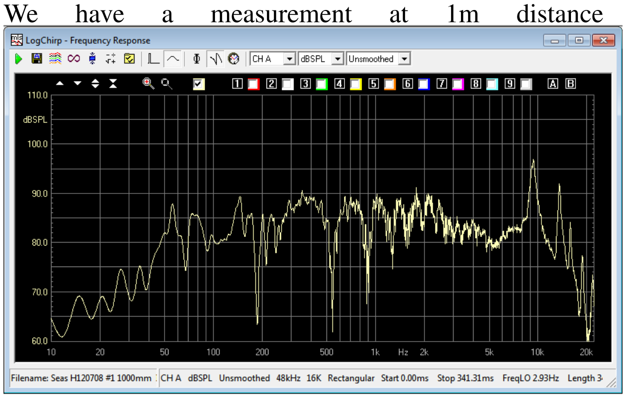

Figure 9. H1207 on Large IEC Baffle measured at 1m.

We then moved to a measurement at 0.1m distance.

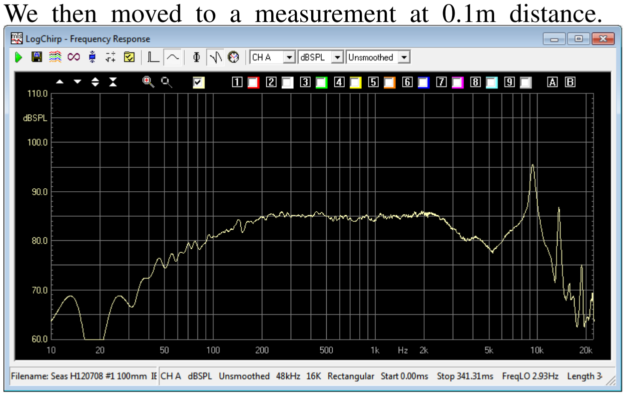

Figure 10. H1207 on Large IEC Baffle measured at 100mm.

At last we can see the "True Anechoic Response" of this drive unit and the Tetrahedral Measurement in figure 5 comes close [8]

[7] Yes I know it's on it's side

[8] the difference between 2kHz and 5kHz is due to the close proximity of the acoustic absorption to the microphone in the TTC 350

5. CONCLUSION(S)

The new method for measuring the Acoustic Performance of a Loudspeaker Driver or Transducer described earlier has been verified by independent measurements using Near Field, Far Far Field and Anechoic Measurements made independently by other people.

These measurements are based upon using a Tetrahedral shaped enclosure with fixed Geometry and interchangable baffles. These allow rapid changeover between differing measurements together with very high consistency and measurement stability.

The measurements in this report demonstrate that the measurements from a Tetrahedral Test Chamber can approach the standards or in some cases exceed those of Anechoic Measurements.

The next stage is to get this technique adopted more widely and standardised so that we can verify it throughout the the supply chain and gain the benefits of improved loudspeaker driver measurements.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

(1) Consistently Stable Measurements using a Tetrahedral Enclosure - E-brief #123, AES Oct 2013
(2) Alan S. Phillips, 'Measuring the True Acoustical Response of Loudspeakers', SAE (2004)
(3) Hill Acoustics, www.hillacoustics.com
(4) SEAS Fabrikker AS of Norway www.seas.no
(5) ABEC 3 & Vacs, www.randteam.de
(6) Pafec, www.vibroacoustics.co.uk
(7) Richard Small, 'Simplified Loudspeaker Measurements at Low Frequencies', JAES (1972)
(8) D.B.Keele,'Low-Frequency Loudspeaker Assessment by Nearfield Sound Pressure Measurement', JAES (1974)
(9) CLIO www.audiomatica.com
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